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ABSTRACT

Graphing calculators present a challenging task for mathematics teachers in the classroom. This digest offers four distinct methods for using graphing calculators in mathematics classrooms, including: (1) tools for expediency; (2) amplifiers for conceptual understanding; (3) catalysts for critical thinking; and (4) vehicles for integration. Resources are provided for each method. (ASK)

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As predicted by the National Council of Teachers of Mathematics (NCTM) in their series of reform documents (*Curriculum and Evaluation Standards*, 1989; *Professional Standards*, 1991; *Assessment Standards*, 1995), graphing calculators have presented a challenging task for mathematics teachers in today's classrooms. Faced with the power of a small and easy-to-use computer, teachers must reconsider the mathematical content, educational methods, and assessment strategies that they employ. In a world of accessible technology, the very nature of mathematics and what it means "to do mathematics" is called into question. Not unlike the painstaking infusion of four-function calculators into the elementary curriculum, graphing calculators are redefining the notion of demonstrated knowledge in secondary mathematics.

With calculators that can do so much more than simple arithmetic, increasing attention has been devoted to developing materials that enrich learning experiences in mathematics. Four distinct types of enrichment have been identified, and this digest provides a sampling of references for each. Graphing calculators can be used as: (1) tools for expediency, (2) amplifiers for conceptual understanding, (3) catalysts for critical thinking, and (4) vehicles for integration.

Using Graphic Calculators as Tools for Expediency

It is not surprising that students miss the main objective of a lesson when they are caught in a trap of tedious computation or the point-by-point plotting of a complex graph. Without argument, the graphing calculator reduces the time and effort required to perform cumbersome mathematical tasks.

A Look at Parabolas with a Graphing Calculator describes an exploration involving quadratic equations. The TI-85 graphing calculator is used to solve routine problems associated with second-degree polynomials. In particular, the menu and matrices capabilities of the calculator are emphasized, highlighting the heuristic of solving a system of equations without the burden of multi-step calculations.

Johnson, L.H. (1997, April). A look at parabolas with a graphing calculator. *Mathematics Teacher, 90*(4), 278-282.

Sold on a New Machine presents opinions of high school teachers on using the graphing calculator in lower and upper level math courses. An underlying theme centers on allowing students to graph equations that would, if plotted manually, consume hours of important instructional time.

West, P. (1991, October). Sold on a new machine. *Teacher Magazine, 3*(2), 18-19.

Retaining a Problem-Solving Focus in the Technology Revolution offers guidelines for determining when to use mental math, paper-and-pencil, or technology-assisted methods when attacking mathematical problems. Determining the rational roots of a polynomial provides a means for comparing the graphing calculator approach to other solution strategies. Suggestions for curricular planning are included.

Duren, P.E. (1989, October). Retaining a problem-solving focus in the technology revolution. *Mathematics Teacher, 82*(7), 508-510.

Using Graphing Calculators as Amplifiers for Conceptual Understanding

Graphing calculators are capable of providing multiple representations of mathematical concepts. By building tables, tracing along curves, and zooming in on critical points, students may be able to process information in a more varied and meaningful way. To enhance understanding, it appears that working with representations that expose diverse aspects of a concept is critical.

Sharing Teaching Ideas: The Graphing Calculator and Division of Fractions suggests using a graphing calculator to demonstrate that dividing a fraction is the same as multiplying by the reciprocal. Primarily intended for a middle school audience, this article describes an activity that has students graphing a division problem and an equivalent problem (multiplying by the reciprocal). The use of a graphic representation for each of the problems provides convincing evidence that these two arithmetic processes are identical.

Pelech, J., & Parker, J. (1996, April). Sharing teaching ideas: The graphing calculator and division of fractions. *Mathematics Teacher, 89*(4), 304-305.

The Effect of Graphing Calculators on Students' Conceptions of Function presents the results of a year-long study of topics in an Algebra II classroom. Participating students were taking a course that made significant use of graphing calculators, and the positive effects of graphing calculator usage are presented, particularly on tasks that required graphical thinking. Misconceptions resulting directly from the use of graphing calculators are also discussed.

Slavit, D. (1994, April). *The effect of graphing calculators on students' conceptions of function.* [ED 374 811]

Student Understanding of Basic Calculus Concepts: Interaction with the Graphics Calculator describes the intuitive notions of five college and two high school students regarding function and limit. Episodes where student comprehension seemed to be influenced by the availability of graphing calculators illustrate the power of multiple representations in deepening mathematical understanding.

Lauten, A. D., et. al. (1994, June). Student understanding of basic calculus concepts: Interaction with the graphics calculator. *Journal of mathematical behavior, 13*(2), 225-237.

Multiple Representations: Using Different Perspectives to Form a Clearer Picture presents a teaching unit that intentionally introduces a variety of methods for solving quadratic inequalities. During teacher-led instruction, students were shown how to use cases and critical numbers as strategies in finding solutions to quadratic inequalities. In addition to the symbolic method demonstrated, students were able to view pictoral representations of the inequalities on their graphing calculators. When students worked on their own, most chose graphical methods for finding solutions.

Piez, C. M., & Voxman, M. H. (1997, February). Multiple representations: Using different perspectives to form a clearer picture. *Mathematics Teacher, 90*(2), 164-166.

Explorations: Discovering Math on the TI-92 provides twelve innovative and practical activities by practicing teachers that illustrate how to begin using the TI-92

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in high school classrooms. Many different content areas are covered, from beginning algebra to advanced calculus. Each lab purposefully uses multiple representations for learning about a topic, and most offer suggestions for extending the investigations.

Brueningsen, C., et. al. (1996). *Explorations: Discovering math on the TI-92*. Ausin, TX: Texas Instruments Incorporated.

Using Graphing Calculators as Catalysts for Critical Thinking

When wearisome computation and plotting tasks are minimized, students can become engaged in answering "what if" questions. The thought of changing the premises of a mathematical argument grows more attractive if the chore of executing those changes is easier. Moreover, the graphing calculator promotes autonomy in asking questions, encouraging students to pose their own problems.

Problem-Based Mathematics – Not Just for the College-Bound contains an abridged description of The Interactive Mathematics Program, a comprehensive, standards-based high school mathematics curriculum. Aimed at replacing the traditional sequence of mathematics courses, IMP emphasizes using graphing calculators to enhance students' critical thinking skills. Produced by a National Science Foundation initiative, this four year program integrates content strands and focuses on problem-solving processes.

Alper, L., et. al. (1996, May). Problem-based mathematics – Not just for the college-bound. *Educational leadership, 53*(8), 18-21.

Investigating a Definite Integral – From Graphing Calculator to Rigorous Proof suggests that the graphing calculator can be used as a springboard for discovery. While learning how to calculate definite integrals, students in an advanced calculus class proposed their own theorem concerning integration. While using the graphing calculators to investigate quick solutions to problems, the students formulated conjectures that eventually led to a rigorous proof.

Touval, A. (1997, March). Investigating a definite integral – from graphing calculator to rigorous proof. *Mathematics Teacher, 90*(3), 230-232.

Explorations: 92 Geometric Explorations on the TI-92 is an activity book that motivates geometry students to look for patterns, form conjectures, and justify arguments. Using the dynamic geometry capabilities of the TI-92, students become interested in explaining why objects relate to each other in specific ways. The underlying tenet of "proof as explaining" surfaces in each lab, whether students are uncovering basic theorems or creating advanced constructions. Although not written as a replacement for textbooks, Explorations provides supplementary teaching material that strongly supports critical thinking.

Keyton, M. (1996). *Explorations: 92 geometric explorations on the TI-92*. Austin, TX: Texas Instruments Incorporated.

Using Graphing Calculators as Vehicles for Integration

Many math educators view "integration" as an ill-defined term. Does it mean to bridge the many content strands within mathematics? Is it the marriage of mathematics to other disciplines? Can it be used to describe connecting mathematics to the real world? Luckily, despite how the word is ultimately construed, the graphing calculator supports each of these aspects of integration.

Teaching Discrete Mathematics with Graphing Calculators challenges the belief that graphing calculators are most useful in classes built around continuous topics, such as precalculus and calculus. In fact, rather than looking at smooth curves, the author provides examples of graphing calculator lessons that can help to connect ideas of algebra, geometry, measurement, and probability and statistics. In addition to utilizing the power of being able to graph functions, this article contains activities that help the reader learn about the programming capabilities of graphing calculators.

Masat, F. E. (1994). *Teaching discrete mathematics with graphing calculators*. ERIC Document: ED 380 282.

Modeling Motion: High School Math Activities with the CBR and *Math and Science in Motion: Activities for Middle School* present physics labs that involve using the graphing calculator in conjunction with the Calculator-Based Ranger (CBR). The CBR is a stand-alone motion data collection device that sends information to a TI graphing calculator for analysis. Although the CBR works with most Texas Instruments graphing calculators, these books provide detailed instructions for analysis on either the TI-82 or the TI-83.

Antinone, L., et. al. (1997). *Modeling motion: High school math activities with the CBR*. Austin, TX: Texas Instruments Incorporated.

Brueningsen, C., et. al. (1997). *Math and science in motion: Activities for middle school*. Austin, TX: Texas Instruments Incorporated.

Real-World Math with the CBL System contains 25 activities that use Calculator-Based Lab technology. After connecting the CBL to any Texas Instruments graphing calculator, probes can be selected that collect data related to a variety of scientific phenomenon (everything from light intensity to pH levels). This workbook was designed to provide math students, from algebra through calculus, with innovative ways to explore real-world applications of mathematical concepts.

Brueningsen, C., et. al. (1995). *Real-world math with the CBL system*. Austin, TX: Texas Instruments Incorporated.

Summary

The resources listed here constitute only a small sample of those available. Readers may find that any article or book about the use of graphing calculators in mathematics teaching could easily fit into more than one of the four categories delineated (or perhaps an entirely new category may be suggested). Regardless of how the materials are classified, however, it is important to note that all of the works manifest a common philosophy, a philosophy that the graphing calculator is an instrument for student empowerment.

References

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics*. Reston, VA: Author.

World Wide Web Resources

Math Forum: Internet Calculator Resources

http://forum.swarthmore.edu/mathed/calculator.search.html

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